Tropical Agricultural Research Vol. 11 1999, 134-142

Combining Ability Analysis in Sunflower *Helianthus annuus* (L.)

D. Sassikumar, A. Gopalan and T. Thirumurugan

Centre for Plant Breeding and Genetics
Tamilnadu Agricultural University
Coimbatore, India

ABSTRACT. *Sunflower, despite its superiority in all aspects among oilseeds, it has not attained its target productivity. This may be due to of inadequacy of hybrids, lack of varieties with high yield potential improper seed filling, lack of self fertile line. To alleviate these problems, combining ability study has been resorted to construct better hybrids. Combining ability for yield and its attributes in sunflower (Helianthus annuus L.) was studied in the crosses obtained through Line × Tester mating design fashion using four CMS lines and 14 testers. The general and specific combining ability variances indicated that the predominance of non-additive gene action for all the traits studied. Among the parents, CMS PET-2, M-140 and 343 B exhibited high per se values for head diameter, 100 seed weight, oil content and seed yield per plant. The parents CMS PET-2, CMS PF and BLC 178 were found to be the best general combiners for most of the traits. The cross combinations CMS F × RLC 215, CMS PET-2 × RHA-RR-1, and CMS I × BLC 178 showed significant per se and positive sca effects for many character especially for key characters contributing to seed yield per plant.*

INTRODUCTION

Sunflower contributes a major share to achieve self-sufficiency in the vegetable oil in India. In Tamil Nadu, sunflower crop is gaining momentum as it is highly remunerative. Sunflower oil has perfection in nutritional properties and is practically free from toxic compounds and has high PUFA content. With the advent of stable cytoplasmic genic male sterility in sunflower, the development of technology for hybrid seed production is very much exploited and practically in use for increasing the productivity in sunflower. In this connection the knowledge of gene action and genetic make up of inbreds are absolutely needed for constructing appropriate breeding programmes to develop a hybrid with desirable attributes. The excellence of a parent depends on its *per se* performance and its persistence. This rests on the mode of inheritance that a particular character carries and could be identified with the assessment of the combining ability of the parental lines.

Allard (1960) pointed out that the choice of parents for hybridisation has to be based on complete genetic information and knowledge of combining ability of parents and not merely on the yield performance of genotype. Many scientists (Griffing, 1956; Rudranaik *et al.*, 1990; Kadambavanasundaram, 1980 and Tyagi, 1988) have also acknowledged the importance of combining ability analysis. Studies regarding combining ability of different inbreds has been conducted extensively but still information is lacking on heterosis and combining aspects in sunflower (Lande *et al.*, 1997) and moreover the inbreds utilized in the present study has not been tested for its combining ability. Hence, a study was undertaken to analyse combining ability of parental lines and hybrids in sunflower involving four cytoplasmic genic male steriles and fourteen testers.

MATERIALS AND METHODS

Four cytoplasmic genic male sterile lines *viz.*, CMSF, CMS PET-2, CMS PF and CMS I, were crossed with fourteen diverse pollinators. These are newly synthesized genotypes which were received from sunflower project coordinator, Bangalore. In rabi 1995, the resultant hybrids along with parents, hybrid check KBSH-1 and a varietal check C0-4 were studied for nine characters. KBSH-1 and CO-4 was taken as check for comparison as these were considered to be the best performers in Tamil Nadu in comparison with their contemporary hybrids and varieties respectively. All the entries were randomised and raised in single rows of 4 m length with a spacing of 60 cm between rows and 30 cm between plants within a row. This set was raised in 3 blocks with three different randomisation conferring Randomised Complete Block Design. Recommended agronomic practices were followed.

The observations were recorded on five randomly selected plants in each plot for days to 50% flowering, (number of days from sowing to flowering when 50% of the plants in a row started flowering) plant height, (measured in cm from ground level to the base of the capitulum) stem girth, (at the time of harvest the circumference of the stem was measured at the fourth node using thread and expressed in cm with the help of scale) number of leaves per plant (the number of productive leaves from ground level to the tip of the plant including side branches was counted), head diameter (maximum width at maturity) 100 seed weight, husk content [a known weight (W1 g) of well filled seeds sampled out from each genotype. The hull was removed and the weight (W2 g) was recorded. The hull weight with reference to kernel weight was expressed in percentage] oil content [using Nuclear Magnetic Resonance (NMR) spectrometer (oxford 4000 series)] and seed yield. The mean values were subjected to combining ability analyses and estimation of variance components was made as per line × tester mating design (Kempthorne, 1957).

This model fits well with this experiment as this can be employed for larger number of parents and for CMS lines. The analysis was done using the SPAR-1 computer package.

RESULTS AND DISCUSSION

The analysis for the relative estimates of variances as cited in Table 1 revealed that the variances due to parents, testers and hybrids were highly significant for all the characters studied.

Table 1. Analysis of variance (mean squares) of combining ability for nine characters in sunflower.

Source of Variation	D.F.	Days to 50% flowering (days)	Plant height (cm)	Stem girth (cm)	No. of leaves per plant (No.)	Head diameter (cm)	100 seed weight (g)	Husk content (%)	Oil content (%)	Per plant seed yield (g)
Parents	17	4.50**	754.51**	2.81	11.17**	5.30**	1.94**	184.84**	25.31**	120.09**
Lines	3	3.00	606.41**	1.48*	9.66	1.46	1.16*	455.93	7.47	128.98**
Testers	13	5.19**	802.77**	3.33**	10.23*	5.04**	2.26**	71.13**	31.11**	127.23**
Line × tester	39	14.75**	44.70**	0.91**	39.03**	3.45**	0.72**	88.94**	17.64**	211.54**
Line *vs* tester	1	0.078	571.41	0.07	27.95**	20.18**	0.08	849.69**	3.44	0.557
Hybrids	55	11.76**	254.52**	1.51**	30.62**	3.72**	1.11**	104.75**	20.27**	187.11**
Error	146	1.06	17.57	0.12	3.36	0.77	0.08	4.58	2.40	6.16
σ^2 *GCA*	-	0.492	-1.860	-0.020	-0.020	0.211	0.034	4.018	1.417	1.301
σ^2 SCA	-	2.855	67.018	0.472	8.945	0.675	0.301	25.197	4.005	58.674
σ^2 *GCA*/ σ^2 SCA	-	0.172	0.027	0.043	0.002	0.312	0.115	0.159	0.353	0.022

* - Significance at 5% level ** - Significance at 1 % level

Variances due to lines (plant height, husk content yield per plant stem girth and 100 seed weight) and line × tester interaction showed significance for characters like plant height, number of leaves per plant, head diameter, husk content. Thus it is evident that wide genetic variability existed in the selected inbred lines for all the characters studied, hence liable for combining ability analysis to partition the variability. Similarly, owing to highly significant ($P<0.01$) L × T variance, specific cross combinations might be differentially superior over others (Sharma, 1998). Moreover, in this investigation, analysis of gene effect exhibited greater SCA variance than *GCA* variance for all the characters studied.

As the ratio between *GCA* and SCA variances falls below one, it implies the pre ponderence of non-additive gene action for the traits studied and confirms the reports of earlier workers (Pathak *et al.*, 1985; MerinKovic, 1993; Nirmala, 1996). Such non-additive gene action among the characters comply that these traits could be improved by heterosis breeding and exploitation of hybrid vigour is also possible with the materials used in the present study. When the parents were probed individually for *per se* performance and *GCA* effects it is observed from the Table 2 and 3 that certain parents had high order of expression for many characters.

Among the lines, CMS PET-2 possessed high *per se* performance for all the traits studied except for days to 50% flowering. Similarly in testers, 343 B recorded high mean values for the traits head diameter, 100 seed weight, oil content and seed yield per plant and M 140 for stem girth, number of leaves, head diameter, 100 seed weight and seed yield per plant. Hence CMS PET-2, 343 B and M 140 were adjudged as best parents with respect to mean performance. This is followed by BLC 178 which displayed high mean values for the traits plant height, head diameter and oil content.

Regarding *GCA* effects, certain genotypes exhibited high *GCA* for more than two characters. Among lines CMS PET-2 has expressed high *GCA* values for the key traits *viz.*, earliness, 100 seed weight, husk content and per plant yield. Similarly testers BLC 178 (plant height, head diameter, low husk content and per plant yield) and RLC 212 (oil content, earliness, number of leaves, 100 seed weight and low husk content) were identified as good combiners for many traits. Besides these BLC 175, 302 B and RLC 215 were noted for their high performance with individual traits. Kadambavanasundaram (1980) stated that parents from high *GCA* effects have better breeding value, when it is associated with high mean performance. Based on this, the genotypes showing high efficiency for both *GCA* effect and mean expression have been taken into account for choosing superior parents.

Table 2. Mean performances of parents for nine characters in sunflower.

Parents	Characters								
	Days to 50% flowering (Days)	Plant height (cm)	Stem girth (cm)	No. of leaves per plant (No)	Head diameter (cm)	100 seed weight (g)	Husk content (%)	Oil content (%)	Yield per plant (g)
LINES									
CMS F	57.67	123.39	4.28	23.27	9.13	2.68	34.31	35.87	26.09
CMS I	55.67	92.38	4.11	19.53	10.50	2.67	25.97	35.79	26.23
CMS PET-2	57.00	108.97	4.85	23.40	10.69	3.96	31.75	39.16	38.67
CMS PF	55.67	95.34	5.67	22.13	10.25	3.37	34.25	36.61	36.07
TESTERS									
RLC 204	56.33	107.16	3.25	17.53	7.89	1.75	25.68	36.35	33.09
RLC 201	58.67	103.74	4.60	21.61	9.06	1.81	27.87	33.57	27.53
302 B	55.67	109.82	5.57	22.67	8.24	3.33	33.74	32.81	27.16
BC-3-1-R	56.67	99.99	6.00	22.47	9.38	4.28	25.17	34.85	37.17
RHA-RR-1	54.67	89.13	3.33	16.93	7.09	1.40	37.48	31.97	23.57
BLC-175	55.67	100.47	5.24	18.80	7.10	3.86	19.03	38.59	27.25
BLC-178	58.33	124.04	4.48	21.23	10.57	3.24	21.41	40.21	29.78
RLC-215	55.33	55.62	2.87	17.80	7.63	3.42	25.64	40.15	37.13
BLC-168	57.00	95.07	4.50	21.56	8.12	2.58	26.97	31.65	28.48
RLC-212	56.67	103.32	5.54	20.87	9.99	3.54	32.92	38.91	35.34
BLC-166	58.33	110.57	4.79	20.73	8.24	3.16	27.42	38.11	33.19
M-140	54.67	91.95	5.88	21.40	10.56	3.77	26.07	35.72	41.20
343 B	55.33	78.04	5.46	20.20	10.31	3.68	23.51	40.83	44.58
M130	56.33	91.81	3.42	21.13	7.19	3.28	25.47	33.79	22.66
General Mean	56.43	98.93	4.66	20.74	9.0	3.10	29.15	36.39	31.96
CO-4	56.67	111.29	6.15	24.33	10.17	4.28	31.96	36.53	37.82
KBSH-1	59.00	133.92	5.93	30.00	11.31	3.98	26.31	39.96	41.33

Table 3. Estimates of general combining ability effects for nine characters of parents in sunflower.

Parents	Characters								
	Days to 50% flowering (Days)	Plant height (cm)	Stem girth (cm)	No. of leaves per plant (No)	Head diameter (cm)	100 seed weight (g)	Husk content (%)	Oil content (%)	Yield per plant (g)
LINES									
CMS F	1.01**	-0.24	-0.04	-0.26	-0.63**	0.00	3.43**	-0.74**	-2.73**
CMS I	-0.24	-0.55	-0.24**	-0.88**	0.74**	-0.36*	-1.70**	-0.31	1.76**
CMS PET-2	-1.05**	0.88	0.02	-1.10	-0.12	0.26*	-0.92*	-1.03**	1.00*
CMS PF	-0.19	-0.10	0.27**	0.48**	0.00	0.10	-0.81*	2.08**	-0.03
SE of lines	0.13	0.44	0.04	0.23	0.11	0.04	0.25	0.20	0.28
TESTERS									
RLC 204	-0.55	-4.04	-0.34**	-3.25**	0.02	-0.02	3.67**	-1.57**	1.42
RLC 201	-0.55	0.59	0.04	0.44	-0.83*	-0.48	-2.71	0.78	-5.42
302 B	-1.30**	-9.25**	-0.45**	-1.14	-0.83*	-0.12	9.25**	0.38	-1.31
BC-3-1-R	1.37	1.03	0.06	-0.19	0.59	-0.51**	1.91**	0.72	-2.74**
RHA-RR-1	0.87*	1.41	0.17	1.77**	0.12	0.22*	-2.79**	-3.09**	1.20
BLC-175	1.45**	5.90**	0.31*	0.71	0.31	0.29*	0.18	1.37*	6.13**
BLC- 178	1.20**	10.31**	0.24	0.66	1.23**	0.18	-4.65**	0.57*	2.37**
RLC-215	-0.13	-1.64	0.04	-2.83**	0.02	0.10	-2.17**	0.70	-7.05**
BLC-168	0.88	-6.50**	-0.27*	1.20	0.46	0.26	-1.96**	0.40	-3.17
RLC-212	-1.05	-1.00	0.21	1.41*	-0.29	0.27*	-3.58**	1.35*	1.13
BLC-166	0.45	2.78*	0.02	-0.70	-0.27	0.13	0.13	0.20	-3.78**
M-140	-0.38	-1.12	-0.07	0.75	0.20	0.28*	-1.22	0.43	0.42
343 B	-1.46**	-5.81**	0.11	0.50	-0.51	-0.2*	0.42	0.05	0.57
M130	-0.95*	7.36**	-0.07	1.65*	-0.21	-0.33**	-0.82	-2.30**	-3.86**
SE of Tester	0.27	0.92	0.09	0.48	0.23	0.08	0.51	0.41	0.58

* - Significance at 5% level ** - Significance at 1% level

Thus lines CMS PET-2, CMS PF and testers BLC 178 and RLC 212 may be recommended for any crossing programme. It can be concluded that crossing CMS Pet-2 and CMS PF with the tester BLC 178 may result in superior segregants with favourable genes for the above said traits.

The best hybrids from the present study have been selected based on the criteria used for identifying superior parents. The hybrids with the high order of *per se* performance identified were CMS F × RLC 215 (head diameter, 100 achene weight, oil content and seed yield per plant) followed by CMS PF × BLC 175, CMS I × BLC 178 and CMS PET-2 × RHA-RR-1 for three characters each (Table 4). With reference to sca, CMS F × RLC 215 is adjudged as the best hybrid as it showed significant effects for seven characters, trailed by CMS F × T 215, CMS I × BLC 178 and CMS PF × 343 B.

Table 4. Estimates of specific combining ability effects for seed yield per plant in the crosses and desirable effects for component traits in sunflower.

Male Parents	Female Parents							
	Seed yield per plant				# component traits with desired *sca* effects			
	CMS F	CMS I	CMS PET-2	CMS PF	CMS F	CMS I	CMS PET-2	CMS PF
RLC 204	1.76	-10.13**	3.49*	4.88**	7	3	2, 8	2, 4, 5, 6
RLC 201	10.38**	2.85*	0.26	-13.48**	4, 5, 6, 7	1	2	
302 B	-2.62	-6.41**	8.29**	0.74	3, 7		2, 3, 4, 6	1
BC-3-1-R	-0.12	3.33**	3.29*	-6.51**		2, 7	6, 8	7
RHA-RR-1	-1.09	-3.19*	-2.20	4.49**			1, 2, 4, 6	2
BLC-175	0.73	3.22*	-2.48	-1.47		3, 4	1, 4, 7	2, 3, 4
BLC- 178	-10.54**	9.33**	6.11**	-4.40**	8	3, 5		
RLC-215	7.04	5.32**	4.76**	17.12**	1, 2, 4, 6	1, 2		
BLC-168	1.78	-2.83*	-11.04**	12.09**	2	7	7	
RLC-212	-5.32**	10.39**	-1.73	-3.34			4	
BLC-166	8.26**	-6.24**	-5.04**	3.02		4, 8		3
M-140	-8.34**	1.58	7.68**	-0.92		2	3, 7	
343 B	-8.43**	-0.29	-6.49**	15.21**		3		2, 4, 5
M 130	6.53**	-6.94	-6.91	7.32**		2, 4		3, 6, 7

1. Days to fifty per cent flowering; 2. Plant height; 3. Stem girth; 4. Number of Leaves per plant; 5. Head diameter; 6. 100 achene weight; 7. Husk content; 8. Oil content

The cross CMS F × RLC 215 was adjudged as the best hybrid owing that it displayed significant high values for both *sca* effect and *per se* performance to oil content, head diameter and 100 achene weight.

Similarly, CMS PET-2 × RHA-RR-1 (plant height, number of leaves and 100 achene weight) followed by CMS I × BLC 178 (head diameter and seed yield per plant) can be concluded as a best cross combination for these mentioned traits.

CONCLUSIONS

The genotypes selected for the study are diverse in nature and showed predominantly non-additive gene action for the characters studied. The parents CMS PET-2, CMS PF and BLC 178 have a greater combining ability so that they can yield better segregants. The best hybrid combinations identified were CMS F × RLC 215, CMS PET 2 × RHA-RR-1 and CMS I × BLC 178 among the all the cross combinations of the genotypes studied.

REFERENCES

Allard, R.W. (1960). Principles of Plant Breeding: John Wiley and Sons, Inc., New York and London.

Griffing, B. (1956). Concept of general and specific combining ability in relation to diallel crossing systems. Aus. J. Biol. Sci. 9(4): 463-494.

Kadambavanasundaram, M. (1980). Combining ability and its impact on breeding procedures. *In*: Proc. Summer Inst. Theoretical and Applied Aspects of Exploiting Heterosis in Crop Plants. Tamilnadu Agric. Univ., Coimbatore.

Kempthorne, O. (1957). An Introduction to Genetical Statistics. John Wiley and Sons Inc., New York. pp. 458-471.

Lande, S.S., Weginwar, D.G., Patel, M.C., Limbore, A.R. and Khorgade, P.W. (1997). Gene action, combining ability in relation to heterosis in sunflower (*Helianthus annuus* L.) through Line × Tester analysis. J. Soils and Crops. 7(2): 205-207.

MerinKovic, R. (1993). Combining ability of some inbred sunflower (*Helianthus annuus* L.) lines. Indian J. Genet. 53(3): 299-304.

Nirmala, V.S. (1996). Evaluation of CMS lines in sunflower (*Helianthus annuus* L.) for combining ability and heterosis. M.Sc. (Agri) Thesis, TNAU, Coimbatore.

Pathak, A.R., Singh, B. and Kukadia, M.V. (1985). Combining ability analysis in sunflower (*Helianthus annuus* L.). Ind. J. Herid. 17(3/4): 12-22.

Rudranaik, V., Shanta, R., Hiremath. and Giriraj, K. (1990). Combining ability for yield and its attributes in sunflower. J. Oilseeds Res. 7: 65-68.

Sharma, J.R. (1998). Statistical and Biometrical Techniques in Plant Breeding. New Age International Publishers, India. pp. 139-146.

Tyagi, A.P. (1988). Combining ability analysis for yield components and maturity traits in sunflower (*Helianthus annuus* L.). Pro. 12th International Sunflower Conference, 25-29 July, 1988. Novi Sad, Yugoslavia. pp. 489-493.